Emission Spectra and Excitation Functions of CS₂, NO, N₂O, and NO₂ by Low Energy Electron Impact

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Emission spectra of CS₂, NO, N₂O, and NO, in the region 240-650 nm and their excitation cross section curves (excitation functions) were obtained under low energy electron impact (2-25 eV) at a gas pressure of 10⁻⁶-10⁻⁵ Torr. The excitation functions obtained were for the following processes: (1) CS₂ → CS₂*, (2) NO → NO (A)*, (3) N₂O → N₂(C₃IIu) + O, (4) N₂O → NO₂* + e⁻, (5) NO₂ → NO₂*, (6) NO → NO (A and/or B) + O.

The lowest emission state of 3Σ⁺* besides the 3A₂ state for CS₂ was observed in the region 400-600 nm. The excitation function for NO₂ supported the existence of the two emission states (the doublet and quartet states) in the region 400-600 nm. Some resonant peaks were found in the excitation functions for CS₂, NO, and NO₂. The apparent features of the curves for the process (4) were consistent with the threshold law.

1. Introduction

The purpose of this experimental method is to investigate about excited species and the primary process of formation under electron impact. In the excitation of a molecule by low energy electron impact the following two types of the excitation process may occur in addition to the ordinary singlet-singlet excitation by light absorption: (1) A singlet-triplet excitation which is resulted via the electron exchange in the inelastic scattering between an incident electron and a molecular electron. (2) A resonant excitation which is caused by an inelastic scattering in the formation of a temporary negative-ion complex.

These excitation processes can be distinguished from each other to a certain degree on the basis of the features of the excitation functions. As seen above, the study on these problems may have the following meaning: (1) It gives some informations about the phenomenon in electron impact and contributes fundamental knowledges to mass spectrometry. (2) It provides a method to study on the excited triplet state of molecules and such processes in which the triplet state plays an important role. This also supplements the informations about the excited molecules in photochemistry from another side. (3) It gives the informations of a temporary negative-ion complex. The temporary negative-ion complex has been investigated so far by electron transmission spectroscopy and the mass spectrometric measurement of a negative-ion product. The
method used in the present study also gives another method to study the temporary negative-ion complex. (4) The study closely relates with a primary process in radiation chemistry, in an electric discharge, and further in an electric discharge laser.

2. Experimental

Figure 1 shows a schematic diagram of the apparatus used in electron impact. The left side shows an electron impact system constructed of an electron gun, a collision chamber, and a Faraday cup. The right side shows a detection system of emitted light. An electron beam crossed with an upward molecular flow of the target gas effused from a nozzle in the center of the collision chamber. Thus the effused gas condensed on a liquid-nitrogen trap. The emitted light was focused by a quartz lens on the slit of a Nalumi RM-23 grating monochromator with a Hamamatsu R585 photomultiplier and recorded by a photoncounter with a recorder.

Figure 2 shows a cross sectional view of the electron gun, the collision chamber, and the Faraday cup. They were all made of non-magnetic SUS-32 stainless steel. The slits S₁, S₃, and S₄ are circular plates which are 30 mm in diameter and 1 mm thick. The oxide cathode made by RCA for the electron gun of a cathode-ray tube was used. The cathode and the repeller plate were equipotential with ground. The apertures S₂, S₃, and S₄ were equipotential with the collision chamber. The Faraday cup was kept at +40 V to the collision chamber to collect the secondary electrons in the Faraday cup. The electron beam current was kept constant by a feedback circuit.

The collision chamber and the chamber of the electron gun assembly were separately evacuated by the diffusion pumps. The pressures of the chambers were monitored by the ionization gauges attached to the back walls of the chambers. The highest vacuum in the chambers was $2 \times 10^{-7}$ Torr. The chamber of the electron gun was always kept at the vacuum

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Fig. 1. Schematic diagram of the apparatus.
Fig. 2. A cross sectional view of the electron gun, the collision chamber, and the Faraday cup.
C: oxide cathode, H: heater for oxide cathode (6.3 V, 600 mA), R: repeller plate, S₁: aperture with 3 mm diameter, S₂: aperture with 3 mm diameter for both acceleration and differential pumping, S₃: aperture with 4 mm diameter and equipotential to S₁ and S₂, S₄: aperture with 3 mm diameter, F: Faraday cup with a gold plate at the bottom, N: nozzle with 1 mm diameter and 10 mm length, L: leads, M: mirror, S: solenoid coils for collimation of electron beam, T: cylindrical liquid-nitrogen trap.

\[ \text{N}_2 \quad C^3\Pi_u \rightarrow B^3\Pi_g \]

Fig. 3. Emission spectrum of N₂. Only the second positive band system (N₂, C→B) is seen and the first negative band system (N₂⁺: B→X) is absent because the energy of electron of about 14 eV was lower than the ionization energy for the N₂⁺ (B) state.

of \( \sim 10^{-7} \) Torr to protect the oxide cathode from the damage by the contact with the target gas.

Figure 3 shows an emission spectrum from the excited N₂ in the 280-440 nm region. In order to examine the reliability of our apparatus we obtained the excitation function of the \( C^3\Pi_u \rightarrow B^3\Pi_g \) emission and compared this...
Fig. 4. A linear relationship between the emission intensity of $N_2$ at 337.1 nm and the electron beam current at the $N_2$-pressure of $4 \times 10^{-6}$ Torr.

Figure 4 shows the linear relationship between the intensity of the $C^1\Pi_u \rightarrow B^1\Pi_g$ emission of $N_2$ and the electron beam current. Likewise, Fig. 5 shows the linear relationship of the emission intensity with the pressure of nitrogen in the collision chamber. The linear relationships indicate that the excited $N_2$ was formed from single collision with an incident electron under the given conditions of the pressure of $10^{-7}$-10$^{-5}$ Torr in the collision chamber and the electron beam current of 0-21 $\mu$A.

The profile of the excitation function shown in Fig. 6 for nitrogen in the $C^1\Pi_u$ state is a typical one for an electron exchange inelastic scattering. The abscissa has been corrected to fit the observed peak position to that so far obtained by Finn. This curve is in good agreement with that obtained by Finn et al.\textsuperscript{11}

![Graph](image1)

![Graph](image2)

![Graph](image3)

Fig. 5. A linear relationship between the emission intensity of $N_2$ at 337.1 nm and the $N_2$-pressure at the electron beam current of 5.0 $\mu$A.

Fig. 6. Excitation function of $N_2$ (337.1 nm). The maximum point was used to correct the energy of incident electrons.

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agreement with the excitation function so far observed using a high resolution electron spectrometer with a typical energy half width of 0.05 eV FWHM. The peak position of this curve was used to correct the incident electron energy. The shift in the electron energy is mainly due to the difference of the work functions (i.e., the contact potential) between the cathode and the aperture Si.

If the energy width of the incident electrons mainly depends on the energy distribution of the thermally emitted electrons at the cathode temperature, the energy width of 0.21 eV is estimated using the Boltzmann distribution law assumed for the working temperature of 1240°C for the oxide cathode. The energy width of 2kT is assumed according to reference (2). Though there are other factors to increase the energy width the value (0.21 eV) may not be so far from the actual value. This is supported from the result that the energy difference of 3.0 eV between the threshold energy and the maximum point in the excitation function shown in Fig. 6 is in good agreement with the value (3.0±0.05 eV) in reference (1).

3. Results

3.1 Carbon Disulfide

In the present section two emission states involved in the emission spectra of 340-650 nm region are examined in more detail under electron impact. And the primary processes of their formation under electron impact are discussed from the excitation functions in the region of 2-18 eV.

Rosenkrantz and Wagner9, and Arnold and Kimbell8 have observed an emission spectrum in the region of 340-650 nm from the shock-heated CS2/Ar mixtures. Rosenkrantz and Wagner9 have assigned it to the 3A1 state, whereas Arnold and Kimbell8 have assigned it to hitherto unrecognized 3Σg state whose existence had been postulated by Mulliken9.

The lowest 3Σg state has been estimated to be at ν000 = 57 kcal·mol⁻¹ (2.4 eV) which is 0.8 eV below the R-system (3A2) with ν000 = (74 kcal·mol⁻¹, 3.25 eV). Arnold and Kimbell8 have further observed some afterglow emission spectra in the same region for pure CS2 and the CS2/Ar mixture under microwave discharge. The emission state has been assigned to the 3A1 state. Brus7 has observed two exponential decays of 337.1 nm laser excited CS2 fluorescence in the region of 367.5-555.0 nm. He has found two fluorescing states with collision-free lifetimes of 2.9±0.3 and 17±2.2 μsec. He has proposed that there are B2 of 3A1 (3Δu), B2 of 3A2 (3Σu⁻), and 1A2 (1Σg⁻) in the region of S and U bands.

Figure 7 shows the emission spectra from the excited CS2. They have a band structure in the 420-650 nm region and have a continuous band in the 350-420 nm region. The emission spectrum at the excitation energy of 3.1 eV appears in the 400-600 nm region. The emission intensity is considerably larger than that of NO2 which is discussed in the following section. This difference may be due to the strong spin-orbit coupling in the heavy atoms in the excited triplet state of CS2.

Figure 8 shows the excitation functions which were obtained at the wavelengths of 550, 450, and 375 nm, respectively. The excitation functions have three narrow peaks in the lower energy region than ca. 14 eV. The monotonous increase in the higher energy region than ca. 12 eV is mainly due to the emission from the excited CS2⁺.

Figures 9 and 10 show the linear relationships between the emission intensities and both the electron beam current and the pressure of CS2 gas, respectively. These results show that the excited CS2 is formed from single collision with an incident electron under the experimental conditions.

Emission States of CS2—Kleman8 (1963)
Fig. 7. Emission spectra of CS$_2$. Band passes are 3.3 nm for (1) and 6.6 nm for (2), (3), and (4). Electron beam current: 5.0 µA. The CS$_2$-pressure of $4 \times 10^{-6}$ Torr in the collision chamber are same as all of them.

Fig. 8. Excitation functions of CS$_2$ at the wavelengths of 375 nm (●), 450 nm (○), and 550 nm (◆). Bandpasses of all: 6.6 nm. The CS$_2$-pressures in the collision chamber are all $4 \times 10^{-6}$ Torr. Electron beam current are 5.0 µA for all of them.
Emission Spectra and Excitation Functions of CS₂, NO, N₂O, and NO₂ by Low Energy Electron Impact

Table 1. Observed threshold energies for each wavelength.

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Threshold Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>375</td>
<td>3.2 eV</td>
</tr>
<tr>
<td>450</td>
<td>&lt;3.2 eV</td>
</tr>
<tr>
<td>500</td>
<td>&lt;3.2 eV</td>
</tr>
<tr>
<td>550</td>
<td>&lt;3.2 eV</td>
</tr>
<tr>
<td>600</td>
<td>3.2 eV</td>
</tr>
</tbody>
</table>

Excitation functions for CS₂—A typical example of core-excited resonance has been observed in the electron transmission spectroscopy of NO molecule. According to Sanche and Schulz, the core-excited resonance forms a temporary negative-ion complex which contains two Rydberg electrons bound by the field of a positive-ion core. They called this state as a grandparent state. The parent state contains a single Rydberg electron bound by the field of the same ionic core. In this model the energy differences among the resonant lines agree with the differences among the excited states of the positive ion.

The excitation functions shown in Fig. 8 have three narrow peaks in the region 3-12 eV. The energy differences among these three peaks

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observed a high resolution spectrum of CS₂ which was labeled R (450-340 nm), S and U (370-325 nm), and V (330-290 nm). The band origin ν₀₀₀ of the R-system is 26187 cm⁻¹ (74 kcal mol⁻¹, 3.25 eV) and the R-system has been first assigned to the ³A₂ state by Douglas and Milton. Mulliken has postulated that the lowest ³Σ⁺ state is 57 kcal mol⁻¹ (2.4 eV) above the ground state. An emission spectrum was observed at the impact electron energy of ≤3.1 eV which is lower than that of the band origin ν₀₀₀ = 3.25 eV of the ³A₂ state. The emission spectrum extends into the region of 400-600 nm, as shown in Table 1 and Fig. 7. This suggests that the emission state may be the ³Σ⁺ state postulated so far by Mulliken. Although the threshold energy was not clearly determined in the present experiments, the threshold energy could be determined to be below the band origin ν₀₀₀ = 3.25 eV of the ³A₂ state. The formation of ³Σ⁺ can be satisfactorily explained from the large singlet-triplet transition probability by an electron exchange inelastic scattering at low electron energy.

The profiles of the emission spectra in the 340-650 nm region observed at the electron impact energies of 3.6, 4.1, and 6.1 eV were similar to what has been assigned to the ³A₂ state by Arnold and Kimbell. As mentioned above the emission spectrum of the ³A₂ state extends in the 340-650 nm region and the ³Σ⁺ state extends in the 400-600 nm region.
Table 2. Ionization energies for CS₂ and peak positions of excitation functions at the wavelengths of 375, 450, and 550 nm for emission spectrum of CS₂.

<table>
<thead>
<tr>
<th>Ionization energies of CS₂ (eV)</th>
<th>peak positions (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>375 nm</td>
</tr>
<tr>
<td>(X) 10.06</td>
<td>6.0</td>
</tr>
<tr>
<td>(A) 12.69</td>
<td>&gt;2.63</td>
</tr>
<tr>
<td>(B) 14.47</td>
<td>&gt;1.78</td>
</tr>
<tr>
<td>(C) 16.19</td>
<td>&gt;1.72</td>
</tr>
<tr>
<td>(D) 16.6</td>
<td></td>
</tr>
</tbody>
</table>

agree with the difference among the three excited states of CS₂+ within experimental error, as shown in Table 2. This suggests that the sharp peaks can be assigned to the core-excited resonances which add the broad peak in the 3-12 eV region of the singlet-triplet excitation. Thus, besides the direct singlet-triplet excitation, the excited states of 3A₂ and 3Σ_u⁺ of CS₂ are formed by the resonant excitation. The reaction schemes for these processes are shown as follows:

\[ \text{CS}_2 \rightarrow \text{CS}^+ \]  (1)
\[ \text{CS}^+ \rightarrow \text{CS}^+ + h\nu \]  (2)

and

\[ \text{CS}_2 + e^- \rightarrow \text{CS}_2^+ \]  (3)
\[ \text{CS}^+ \rightarrow \text{CS}^+_e + e^- \]  (4)
\[ \text{CS}^+_e \rightarrow \text{CS}_2 + h\nu \]  (5)

Process (1) is a singlet-triplet excitation of CS₁ by an electron-exchange inelastic scattering and process (2) is a spontaneous emission of CS₂⁺. These excitation processes give a broader peak in the excitation function compared to that for a resonant excitation.

Process (3) is the formation of a temporary negative-ion complex by a core-excited resonance. Process (4) is a re-emission of a Rydberg electron from a temporary negative-ion complex. At the same time the neutral CS₂⁺ molecules remain in the 3A₂ and 3Σ_u⁺ state. Process (5) of a spontaneous emission of CS₂⁺ follows process (4). These emission processes for the excited CS₂⁺ formed by a core-excited resonance were first observed in the present study.

### 3.2 Nitrogen Oxides

**NO** — The emission spectrum of nitric oxide shown in Fig. 11 is assigned to the γ band system corresponding to the A²Σ⁺→X²Π transition. Fig. 12 shows the excitation function for bands at ca. 270 nm. The threshold energy was 5.3±0.3 eV, which coincides with the spectroscopic value of 5.5 eV. The excitation cross section reaches a peak at ca. 6.7 eV, and descends to a plateau. The most plausible assignment of the peak at ca. 6.7 eV is that it is due to a resonance scattering. Its peak position coincides with that of a strong peak for the temporary NO⁻ ion in electron transmission spectroscopic study by Sanche and Schulz. The β band system of NO due to the B²Π→X²Π transition, which has been studied in chemical excitation, was not found in this experiment. This is probably because of the small direct excitation probability due to the small Franck-Condon factors between the ground state and the lower vibrational levels of the B state.

**N₂O** — An emission spectrum for nitrous oxide (N₂O) shown in Fig. 13 contains two band systems of N₂O⁺ (A¹Σ⁺→X²Π) and N₂ (C³Π→B³Π). The intensities of the two systems are comparable because the spectrum was observed in slightly higher energy than the
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Fig. 11. Emission spectrum of NO at the electron energy of 7.5 eV. The pressure: 6 × 10⁻⁵ Torr. The beam current: 10 μA. The bandpass: 1.7 nm. The spectrum was obtained in the second order diffraction of the monochromator blazed at 500 nm.

Fig. 12. Excitation function of the NO γ bands at ca. 270 nm. Bandpass: 16.7 nm. Beam current: 15.0 μA. Pressure: 6 × 10⁻⁵ Torr.

threshold of N₂O⁺ (A). The N₂O⁺ system would be much more intense than the N₂ (C → B) system in the higher energy region of incident electron.

Figure 14 shows the excitation functions for the two band systems. For the N₂O⁺
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$N_2O$  

\[ 17.0 \text{ eV} \]

$N_2O(X) \rightarrow N_2(C^3\Pi) + O$

This process has been found also in the fluorescence measurement by vacuum ultra-violet irradiation. The observed threshold value was consistent with the value from photon impact (12.9 eV) and the estimated value (12.7 eV) in a thermochemical cycle.

Neither the $\gamma$ nor the $\beta$ emission of NO was found in the electron impact of $N_2O$. This is consistent with the results of photolysis decomposition in which the NO molecules in the A and the B states were formed in the secondary collision.

$NO_2$—The spectra shown in Fig. 15 contain the emission bands of the excited $NO_2$ in the longer wavelength region and the excited fragment NO ($A$ and/or $B \rightarrow X$) bands in the shorter wavelength region. The second order diffractions of the NO ($A, B \rightarrow X$) bands are overlapping on the emission bands of the excited $NO_2$. Fig. 16 shows the excitation function for $NO_2$, and this curve has a sharp peak in the vicinity of the threshold energy of 2.0 eV, and a plateau with some small peaks. Figure 17 shows the excitation function of $NO_2$ at the higher $NO_2$ pressure of $1.5 \times 10^{-5}$ Torr. The peak in the vicinity of the threshold energy becomes weaker compared to the former. The curve shows likewise some small peaks in the high energy region as seen in Fig. 17. The exci-
Emission Spectra and Excitation Functions of CS₂, NO, N₂O, and NO₂ by Low Energy Electron Impact

Fig. 15. Emission spectra of NO₂ and NO (A²Σ⁺ and/or B²Π→X).
(1) The emission bands from NO (A and/or B) appear in the short wavelength region in the electron impact energy of 16.5 eV. Emission bands of second order diffraction of NO (A and/or B→X) and excited NO₂ overlap in the long wavelength region. (2) Emission bands of the excited NO₂ appear in the 400-600 nm region in the electron impact energy of 6.5 eV. Bandpass for (1) and (2): 3.3 nm.

Fig. 16. Excitation function of NO₂ at the wavelength of 490 nm (the bandpass of 9.9 nm), the NO₂-pressure of 4 × 10⁻⁶ Torr, and the electron beam current of 5.0 μA. The emission light of the shorter wavelength than 400 nm was cut by a filter.

Fig. 17. Excitation function of NO₂ at the wavelength 490 nm (the bandpass of 9.9 nm), the NO₂-pressure of 1.5 × 10⁻⁵ Torr, and the electron beam current of 5.0 μA. The emission light of the shorter wavelength than 400 nm was cut by a filter.

tation function of NO* seen in Fig. 18 steeply increases from the threshold energy of 8.8 eV with the increase of the electron impact energy, and then becomes a plateau curve with some peaks in the high energy region.

The low-lying excited states of NO₂ have so far been investigated by the absorption spectra in the 320-1000 nm region and by the theoretical calculations. Gangi and Burnelle have predicted by the theoretical calculations that the ³B→²A₁ emission extends into the 350-620 nm and the ³B→²A₁ emission in 710-1000 nm. Moreover, they have predicted that the emission from the excited quartet states (¹B₂ and ¹A₂) may appear in the visible region. Gangi and Burnelle have predicted that the absorption spectra in the 350-620 nm region is mainly due to the ³B₁→²A₁ transition, while the ¹A₁→²A₁ transition takes a small part.
Though the \(^4\)A_2\(\rightarrow\)\(^2\)A_1 transition is not only spin forbidden, but also symmetrically forbidden, the transition has been theoretically predicted to have a considerably large oscillator strength owing to a strong interaction with the \(^1\)B_2 state. They have explained that this is evidently due to the very small separation between the energies of the \(^4\)A_2 and \(^1\)B_2 states, and also to the fact that the \(^3\)B_2\(\rightarrow\)^2A_1 bands are more intense than the \(^3\)B_1\(\rightarrow\)^2A_1 bands.

We postulate that the emission spectra (2) in Fig. 15 in the 400-600 nm region involve the emission states of \(^3\)B_2 and \(^4\)A_2 for the following reasons. (1) The \(^4\)A_2\(\rightarrow\)^2A_1 transition has a considerably large oscillator strength according to Gangi and Burnelle. This shows that the phosphorescence may be possible to get a sufficient strength to be observable under the following conditions. The \(^4\)A_2\(\rightarrow\)^2A_1 transition is spin allowed by an exchange inelastic scattering between an incident electron and a molecular electron, moreover it is strengthened by the strong interaction between the \(^4\)A_2 state and the \(^1\)B_1 state which have the large oscillator strength in the transitions from the ground state. (2) The \(^4\)A_2\(\rightarrow\)^2A_1 emission by the electron-exchange inelastic scattering has a sharp peak in the excitation function in the vicinity of the threshold energy, as shown in Fig. 16. (3) The peak is relatively weaker in the high NO_2-pressure than that in the low NO_2-pressure, as shown in Figs. 16 and 17. This fact shows that the \(^4\)A_2 state is separately quenched by the collision between the excited quartet NO_2 and the ground state NO_2. In other words, the \(^4\)A_2 state can not go to the \(^1\)B_2 state via radiationless transition by collision. This is consistent with the theoretical results obtained by Hay in which the vertical excitation energy (2.0 eV) of the \(^4\)A_2 state is lower than that (3.80 eV) of the \(^1\)B_2 state. Figure 16 shows that the small peak for the \(^4\)A_2\(\rightarrow\)^2A_1 emission overlaps on the main excitation function for the \(^3\)B_2\(\rightarrow\)^2A_1 emission in the vicinity of the threshold energy. (4) The observed threshold energy (2.0 eV) is not far from the theoretical values which are 3.43, 2.01, 1.12, 3.81 eV for the \(^4\)A_2 state and 3.33, 3.81 eV (the adiabatic energy of 2.1 eV), 3.80, 3.93, 3.03 eV for the \(^3\)B_2 state.

Though some resonance-like peaks which can be seen in the plateau in the higher electron energy region, the peaks were not assigned in the present paper.

In the excitation function for NO formed from the excited NO_2 the observed threshold energy of 8.8 eV is in fairly good agreement with the estimated value of 8.59 eV for the \(^A^2\Sigma^+\) state (v = 0) and 8.76 eV for the \(^B^2\Pi\) state (v = 0) within experimental error. Lenzi and Okabe have obtained the value of 8.66 eV (143.0 nm) for the same dissociation processes in the vacuum ultraviolet photodissociation. The excitation function is likely to take a plateau with small peaks in the higher energy region, the peaks, however, were not assigned in the present paper.
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Table 3. Observed species in the electron impact of nitrogen oxides.

<table>
<thead>
<tr>
<th>parent molecules</th>
<th>excited species</th>
<th>observed emission</th>
<th>dissociation processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>NO (A1Σ⁺)</td>
<td>A→X</td>
<td></td>
</tr>
<tr>
<td>N₂O</td>
<td>N₂O(0,1Σ⁺)</td>
<td>A→X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N₂(C1Πₐ)</td>
<td>C→B</td>
<td>N₂O→N₂(C) + O (1P)</td>
</tr>
<tr>
<td>NO₂</td>
<td>NO₂(1B₁)</td>
<td>3B₁→1A₁</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1A₁)</td>
<td>1A₁→1A₁</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NO(A1Σ⁺) (B1Π)</td>
<td>A→X, B→X</td>
<td>NO₂→NO (A, B) + O (1P)</td>
</tr>
</tbody>
</table>

Summary of Nitrogen Oxides —The excited species observed in the electron impact of the three nitrogen oxides are summarized in Table 3. These were ascertained to be formed primarily from the parent molecules. The fourth column in the table indicates the dissociation processes which were chosen by the comparison between the observed and the estimated threshold values. In this way we could identify not only the fragments whose emission is observed but also their partner fragments. Many researches on electron impact of nitrogen oxides have been done on the emission in the vacuum ultraviolet region and the detection of metastable fragments. The accumulation of these data would become more important for the determination of potential surfaces and the elucidation of reactions via the excited states.

References